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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s) : Riki OKAMOTO et al.

Serial No. : 10/540,418

Filed : June 24, 2005

For : HIGH STRENGTH THIN STEEL SHEET EXCELLENT IN BURRING, ELONGATION, AND ABILITY OF PHOSPHATE COATING AND A METHOD OF PRODUCTION OF THE SAME

DECLARATION UNDER 37 C.F.R. §1.132

SIR:

I, Kunio HAYASHI, a citizen of Japan, declare as follows:

I. Background

(1). I am an employee of Nippon Steel Corporation, Tokyo, Japan. Nippon Steel Corporation, Tokyo, Japan is the assignee of the entire interest in the above-identified patent application.

(2). I graduated in March, 2002 from the Tokyo Institute of Technology in the Master Course of Material Science and Physical Mettallurgy. Since April, 2002, I have been employed by Nippon Steel Corporation, Tokyo, Japan at the Nagoya Research Laboratory engaged in research and development with respect to thin gauge, high strength steel sheet used in automobiles.

(3). I can read and understand the English language. I can read and understand the Japanese language.

(4). I have read and understand the specification, claims and drawings in the above-identified patent application. I have read and understand the prior art references of record in the prosecution of the above-identified patent application, particularly EP 0 974 677 and JP 11-323480.

(5). In the Office Action mailed October 31, 2008 in the above-identified patent application, claims 1 to 3 were rejected under 35 U.S.C. §103(a) as being unpatentable (obvious) over EP 0 974 677 or JP 11-323480.

II. The Present Invention

(1). The present invention provides a high strength, hot rolled steel sheet excellent in burring, elongation, and ability of phosphate coating. The steel composition contains, by mass %, C: 0.02 to 0.08%, Si: 0.50% or less, Mn: 0.50 to 3.50%, P: 0.03% or less, S: 0.01% or less, Al: 0.15 to 2.0%, Ti: 0.003 to 0.20%, and the balance of iron and unavoidable impurities, satisfying the formula; $Mn + 0.5 \times Al < 4$. The microstructure of the steel sheet consists essentially of a substantially two-phase structure of ferrite, having a grain diameter of 2 μm or more, and bainite. The ratio of ferrite of a grain size of 2 μm or more is at least 40%. The steel sheet has a tensile strength of at least 590 N/mm^2.

(2). One skilled in the art of high strength, hot rolled steel sheet understands that the term "burring", as used in the specification and claims of the above-identified patent application, means "hole expandability". The specification of the above-identified patent application, e.g., at page 15, lines 15-20, defines the burring value or hole expandability ratio (%), identified by the symbol "λ", as $\lambda = (d - d0)/d0 \times 100$. This is in accordance with the understanding of the art. The values for λ or hole expandability ratio (%) for the examples of the present invention are set forth in Tables 2-1 and 2-2 at pages 20 and 21 of the specification.

(3). One skilled in the art of high strength, hot rolled steel sheet understands that a high strength, hot rolled steel sheet with a microstructure having a substantially two-phase structure

of ferrite and bainite would contain little to no retained austenite by volume ratio in such a microstructure.

III. EP 0 974 677 (the " '677 patent)

(1). The '677 patent discloses a high strength steel sheet highly resistant to dynamic deformation and excellent in workability, wherein a low S and high Al steel contains Al of 0.15 - 2.0%, and optionally contains Ti of less than 0.3% for promoting a growth of ferrite grains. However, the present invention contains Ti: 0.003 - 0.20% as an indispensable element to cause the precipitation of fine TiC and enable high strength. Only Example 7 in Table 1 of the '677 patent (pages 16-17) discloses Ti in the steel of the '677 patent. Example 7 of Table 1 of the '677 patent discloses C and Si outside the range of the present invention. Further, the C content in all Examples of the '677 patent in Table 1 exceed 0.08% (upper limit of the C content of the present invention).

(2). Attached Fig. 1 shows the relationship between tensile strength and hole expandability in the Examples of the present invention (Tables 2.1 and 2.2) and the '677 patent. Hole expandability of the '677 patent is calculated based on d/d0 shown in Table 4, Row 16 (hole expandability = ((d/d0)/d0 x 100). Tensile strength of the '677 patent is shown in Table 4, Row 2. As shown in Fig. 1, the hole expandability ratio according to the present invention exhibits two times more than that of the '677 patent for the same tensile strength. This is caused by a difference of hardness in hard layer and soft layer.

(3). Retained austenite volume Vo in the '677 patent is shown in Table 3, Row 8. Because the '677 patent contains a large amount of retained austenite volume and the retained austenite induces transformation into martensite by hole expansion working and strain concentrates at a boundary between martensite and ferrite, hole expandability in the '677 patent deteriorates.

(4). Fig. 2, attached hereto, shows the relationship between the carbon content in the steel and the volume fraction of retained austenite. For the '677 patent, carbon content is taken from Table 1, Row 2 and retained austenite volume Vo from Table 4, Row 8. For the present invention, the relationship between carbon content, and retained austenite volume is taken from the research and development records of Nippon Steel Corporation, Tokyo, Japan. As clearly seen from attached Fig. 2, a higher carbon concentration increases the volume fraction of retained austenite. When the C content is more than 0.08%, the volume fraction of retained austenite becomes more than 3%. Therefore, according to the present invention, it is necessary to limit the C content to less than 0.08% in order to restrain the increase of the retained austenite volume fraction. As previously discussed, all Examples of the steel of the '677 patent in Table 1 have a C content of greater than 0.08%.

(5). Fig. 3, attached hereto, shows the relationship between retained austenite volume fraction and hole expandability ratio. The retained austenite volume Vo for the '677 patent is taken from Table 4, Row 8. The hole expandability ratio for the '677 patent is taken from Table 4, Row 16 using the previously discussed formula ((d/d0)/d0 x 100). For the present invention, retained austenite volume and hole expandability ratio data are taken from the research and development records of Nippon Steel Corporation, Tokyo, Japan. As clearly seen from Fig. 3, the higher retained austenite volume ratio deteriorates hole expandability ratio. The retained austenite induces transformation to martensite during burring working in a hole expansion test, and therefore, a hardness difference from the ferrite phase becomes large and cracks increase. On the other hand, little or no retained austenite exists in case of the present invention, a hardness difference between the hard phase and soft phase becomes small, and therefore hole expandability improves.

<u>IV. JP 11-323480 (the " '480 patent")</u>

(1). The '480 patent relates to a steel sheet having a fine structure and contains C: 0.05 - 0.6%, Mn: 1 - 4%, Si: 0 - 3%, Al: 0.01 - 2.5%, Cr: 0 - 2.5%, Mo: 0 - 2.5%, and does <u>not</u> contain Ti. However, the present invention contains Ti: 0.003 - 0.20% as an <u>indispensable</u> element to cause the precipitation of fine TiC and enable higher strength.

Further, regarding the production process, hot rolling of the '480 patent is carried out in a temperature range of the 2 phase region; α (ferrite) + γ(austenite) region. For the steel No. 7g in the Example, hot rolling is finished at a temperature of 650°C { (640°C + 660°C) / 2}, i.e., below Ar_3. On the other hand, hot rolling in the present invention is carried out above Ar_3 transformation temperature (≒ 660°C ; austenite region). If the hot rolling is finished below Ar_3 transformation temperature, elongation remarkably deteriorates, as discussed in the specification of the present application, e.g., at page 12, lines 5-10.

(2). Fig. 4 attached hereto, shows a relationship between tensile strength and ductility. The values for the tensile strength and ductility for the present invention are taken from Tables 2-1 and 2-2 at pages 20-21 of the specification. For the present invention, the Elongation (%) in Tables 2-1 and 2-2 is taken as the measure of ductility.

For the '480 patent, the values for the tensile strength and ductility are taken from Table 2: (kg/mm^2, fractured surface transition temperature (°C) and [0040]). [0040] of the '480 patent states "As shown in Table 2, Steel Nos. 30 - 39, which are hot rolled with the total reduction rate of more than 50% and cold rolled with the reduction rate of more than 70%, have an average ferrite grain diameter of less than 2 μm and volume fraction of more than 40%. These steels exhibit tensile strength of more than 70 kg/mm^2 and fractured transition temperature is less than - 125°C. Specifically, Steel Nos. 36 - 38 have an excellent balance of tensile strength and ductility... ."

The value of tensile strength from Table 2 of '480 patent (kg/mm^2) is converted to MPa and elongation (ductility) for the '480 patent is predicted from the steel composition, process conditions and tensile strength using a metallurgical model.

As clearly seen from Fig. 4, ductility of the steel of the '480 patent is very low. The reason is that if the present inventive steel (low C - low Si-high Al system) is finished with a hot rolling finish temperature of below Ar_3, the ductility value deteriorates because of the ferrite region hot rolling. (See: page 12 of the specification).

(3). Fig. 5, attached hereto, show a relationship between the ferrite volume ratio of a grain diameter of more than 2 μm and elongation. For the present invention, the ferrite volume fraction of a grain diameter of more than 2 μm and the elongation (%) data are taken from the research and development records of Nippon Steel Corporation, Tokyo, Japan.

For the '480 patent, the ferrite volume fraction of a grain diameter of more than 2 μm and the elongation (%) data are taken from Table 2 which discloses "Ferrite grain structure [average grain diameter (μm), volume fraction (%)].

The value of tensile strength from Table 2 of the '480 patent (kg/mm^2) is converted to MPa and elongation (ductility) and ferrite grain diameter are also predicted by a metallurgical model.

From attached Figs. 4 and 5, the example steels of the '480 patent deteriorate the strength-ductility balance. Specifically, in case of the '480 patent, elongation of 800 MPa steel only exhibits the same level of elongation of the present inventive 1000 - 1200 MPa steel. From the above mentioned result, the present invention achieves excellent strength-ductility balance under a high strength condition in accordance with the increase of the ferrite volume ratio having a diameter of more than 2 μm. In the case of Comparative Examples in the '480 patent, tensile strength only reaches 500 MPa even if the ferrite volume ratio having a diameter of more than 2 μm is contained in large amounts and therefore, strength-ductility balance becomes worse.

(4). Regarding the finishing hot rolling temperature, finish hot rolling in the '480 patent is carried out at relatively low temperature, such as lower than Ar_3 + 50°C, and higher than Ar_1 (780 - 590°C, calculated temperature) for grain refinement. On the other hand, the present invention carries out finishing hot rolling at high temperature, such as higher than Ar_3 (900°C in the Examples) for improving ductility.

(5). The comparison of the present invention with the '480 patent is not appropriate because the present invention claims hot rolled steel sheet, and the '480 patent discloses and claims a cold rolled steel sheet.

(6). All examples of the steel of the '480 patent in Table 1 of the '480 patent, i.e., examples 1 to 17 contain more the 0.08%C. In the present invention, the maximum C in the steel is 0.08%. Examples 18 to 24 of Table 1 of the 480 patent are comparative examples.

V. Additional Information

Attached hereto are data sheets for the attached Figs. 1 to 5.

Translations of Japanese language portions of the Tables of the data sheets are as follows.

Table 1: (Nos. 1 - 7 & 11, 12 and 15: Present inventive steel, Nos. 8 - 10, 13, 14: Comparative steel)

Table 2: From left

Upper column: Hot rolling condition, Cooling conditions, Coiling condition.

Lower column: Finishing temperature (°C), Initial slab thickness (mm), Hot rolling speed at final pass (mpm), Final thickness (mm), Strain rate/second, Calculation (log A), ΔT/°C, Equation 2 condition, Average cooling rate (°C/sec), Remarks, Coiling temperature (°C), Equation 2 condition.

Table 3: From left

Steel No., Main phase (Name, Circle equivalent diameter (μm), Deformed structure), Ferrite (Volume fraction %), Retained austenite (Circle equivalent diameter (μm)), Ratio to grain diameter of main phase, Carbon concentration %, Volume fraction (Before pre-stress V (0), After 5% pre-stress V(5), {(V(0) - V(5)} / V (0) }), Martensite (Circle Equivalent diameter (μm), Volume fraction %), Remained structure, M value (Calculated M value, Condition).

Table 4: From left

Steel No., Static tensile strength (Strain rate = 0.001/s) (TS (MPa), YS (MPa), T.E1%, n-value of 1 - 5%, YS x n, TR%, TS x T.E1 MPa%), Pre-stress and BH treatment (Condition of pre-stress, Pre-stress equivalent strain %, BH treatment (Yes, No)), Static tensile strength (Strain rate = 1000/s) (αdyn, Equation *1), Other properties (Weldability; Suitable, not suitable) d/d0, Hole expandability (Ø20.0mm).

VI. Declaration

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Respectfully submitted,

Kunio Hayashi

Kunio HAYASHI

April 8, 2009

Date

Fig.1

RELATIONSHIP BETWEEN TENSILE STRENGTH AND BOLE EXPANDABILITY RATIO

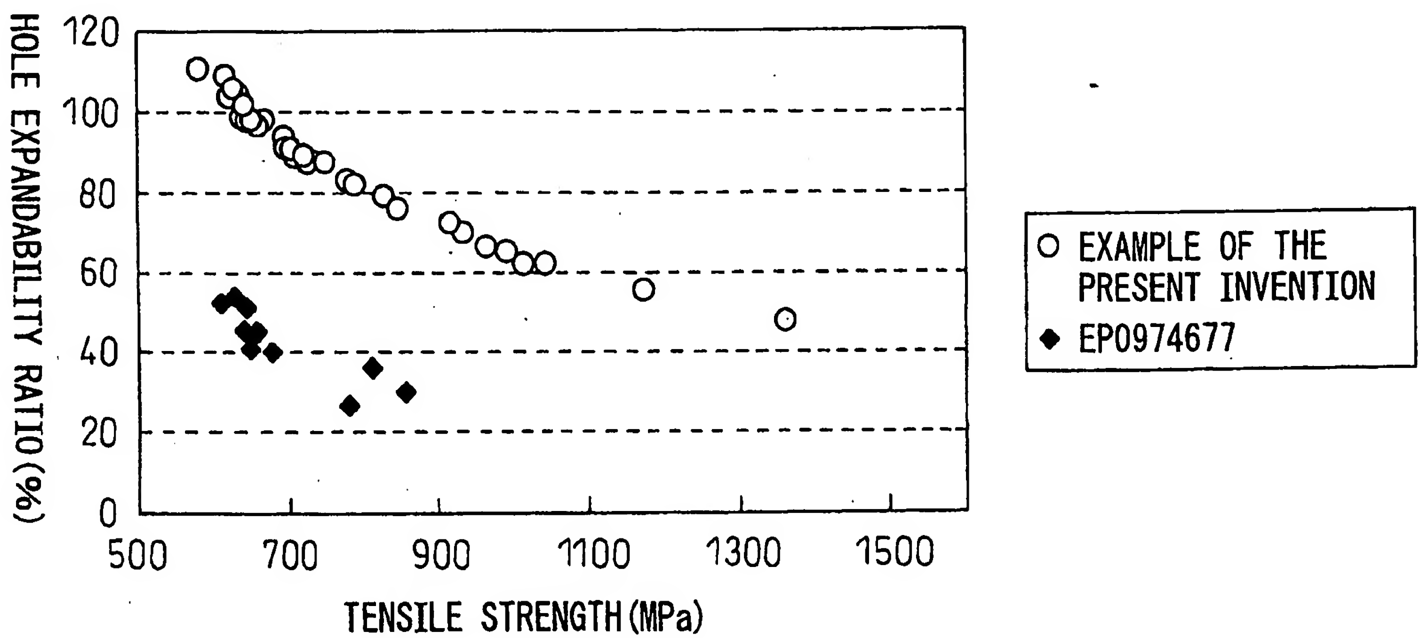

Fig.2

RELATIONSHIP BETWEEN C CONCENTRATION IN THE STEEL
AND RETAINED AUSTENITE VOLUME FRACTION

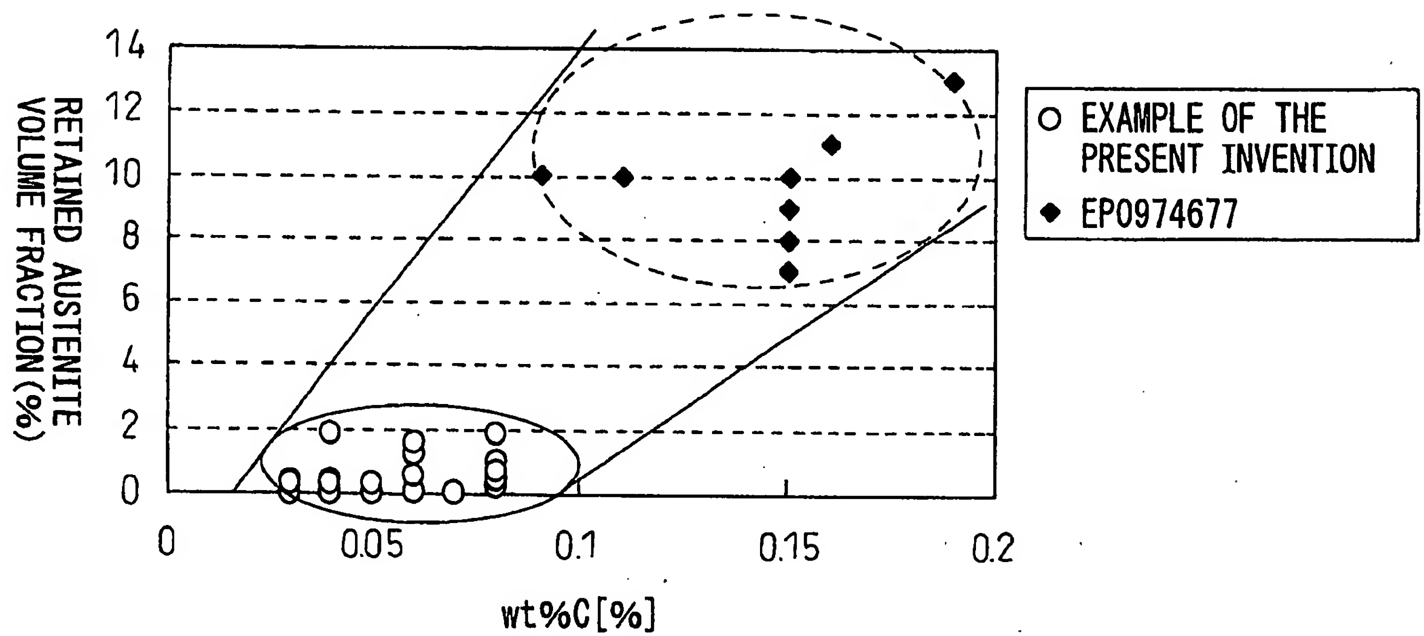

Fig.3

RELATIONSHIP BETWEEN RETAINED AUSTENITE VOLUME FRACTION AND BOLE EXPANDABILITY RATIO

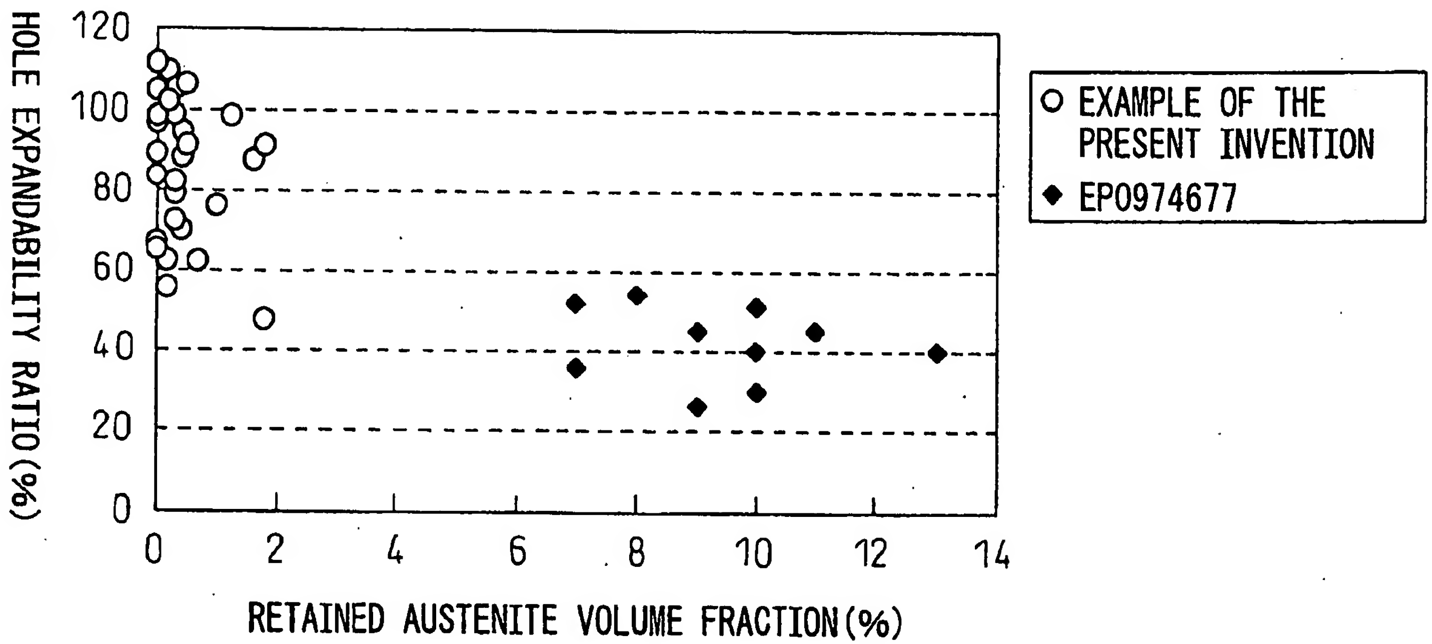

Fig.4

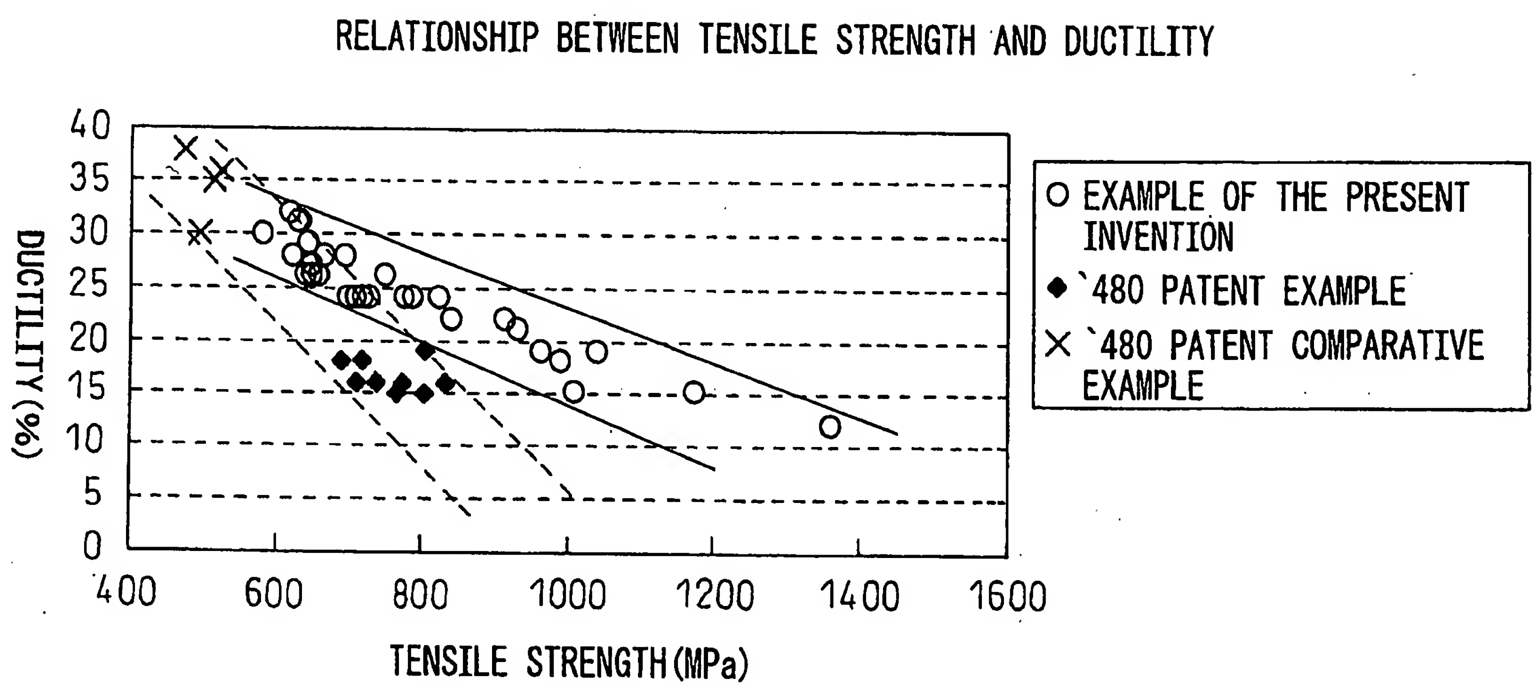
RELATIONSHIP BETWEEN TENSILE STRENGTH AND DUCTILITY
DUCTILITY (%)
40
35
30
25
20
15
10
5
0
400
600
800
1000
1200
1400
1600
TENSILE STRENGTH (MPa)
EXAMPLE OF THE PRESENT INVENTION
`480 PATENT EXAMPLE
`480 PATENT COMPARATIVE EXAMPLE

Fig.5

RELATIONSHIP BETWEEN FERRITE VOLUME FRACTION OF GRAIN DIAMETER OF MORE THAN $2\mu m$ AND ELONGATION

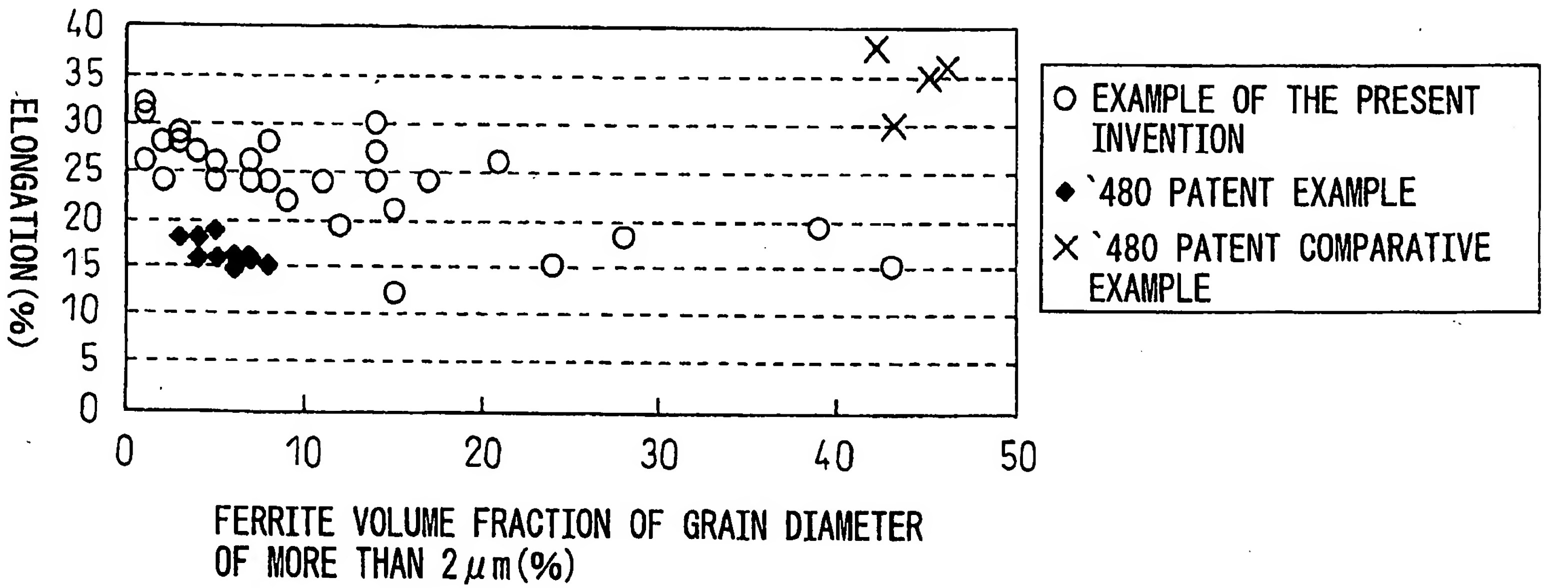

表1 鋼組成成分

	C	Si	Mn	P	S	Al	N	[illegible]	Ni	Cr	Cu	Mo	Nb	Ti	V	B	Ca	REM	[illegible]	Ceq	[illegible]	Ac1	Ac3	Ar3	
1	0.12	1.45	0.99	0.012	0.002	0.02	0.003	1.47											0.96	0.32	0.89	717	858	809	本発明鋼
2	0.13	1.45	0.79	0.012	0.005	0.02	0.005	1.17	0.4								0.004		1.19	0.30	0.89	718	860	808	本発明鋼
3	0.13	1.45	0.89	0.012	0.003	0.02	0.003	1.47		0.89								0.01	1.18	0.37	0.89	711	871	809	本発明鋼
4	0.15	1.45	0.79	0.012	0.003	0.02	0.004	1.17			0.4								1.11	0.38	0.92	711	850	809	本発明鋼
5	0.11	1.30	1.54	0.020	0.003	0.20	0.003	1.58				0.4							1.24	0.37	1.24	701	870	738	本発明鋼
6	0.16	1.60	0.90	0.020	0.003	0.01	0.003	1.81					0.04						0.82	0.31	0.90	709	815	819	本発明鋼
7	0.08	2.10	1.70	0.008	0.001	0.02	0.001	2.12						0.06					1.19	0.39	1.30	703	852	831	本発明鋼
8	0.10	2.00	1.40	0.016	0.001	0.02	0.001	2.01											1.16	0.20	1.10	709	906	833	比較鋼
9	0.10	2.00	1.90	0.015	0.001	0.02	0.001	2.01											1.12	0.29	1.10	710	911	833	比較鋼
10	0.10	2.00	1.10	0.001	0.001	0.02	0.001	2.01											1.17	0.29	1.10	709	916	833	比較鋼
11	0.15	2.00	1.30	0.001	0.001	0.07	0.001	2.00							0.08				1.18	0.44	1.78	720	811	790	本発明鋼
12	0.15	0.11	1.80	0.001	0.001	2.10	0.001	1.71								0.001			1.50	0.33	1.00	703	874	781	本発明鋼
13	0.15	1.50	1.40	0.001	0.003	0.02	0.003	1.83											1.30	0.47	1.50	703	881	807	比較鋼
14	0.11	0.30	1.40	0.010	0.003	0.08	0.003	0.35											1.19	0.10	1.40	731	833	780	比較鋼
15	0.11	1.10	1.50	0.001	0.003	1.04	0.005	3.14											1.30	0.44	1.50	704	874	730	本発明鋼

表2

	熱間圧延条件								冷却条件		巻取条件	
	[illegible]温度℃	[illegible]mm	[illegible]mm	[illegible]mm	[illegible]	[illegible]	ΔT℃	(2)評価	平均冷速℃/秒	備考	巻取温度℃	(3)評価
1	905	33	900	7.0	335	13.46	140	○	41	*1	390	○
2	910	37	500	7.0	336	13.8	150	○	35	*1	180	○
3	900	37	400	7.2	336	13.13	160	○	80		250	○
4	910	34	400	1.8	383	13.51	150	○	90		300	○
5	885	34	700	1.8	180	12.8	170	○	30		450	○
6	840	30	700	1.4	100	13.43	140	○	50		350	○
7	765	35	400	2.1	100	13.13	150	○	80		370	○
8	900	30	400	2.1	90	13.18	150	○	30		353	×
9	736	30	500	2.1	100	13.77	80	×	80		416	×
10	900	29	500	2.1	100	13.77	120	○	50		538	×
11	870	31	700	2.2	100	13.27	130	○	50		310	○
12	875	30	600	1.2	200	14.12	170	○	80		360	○
13	780	30	600	1.2	200	13.49	130	○	15		331	○
14	840	31	300	4.2	210	13.70	100	○	60		340	○
15	860	32	1000	1.2	300	14.09	150	○	104		340	○

表3

鋼番	主相		フェライト	残留オーステナイト						マルテンサイト		組織構成	判定	
	名称	平均粒径μm	体積率%	平均粒径μm	[illegible]比	C濃度%	体積率 [illegible]	体積率 [illegible]	体積率 [illegible]	平均粒径μm	体積率%		計算値	良否
1	フェライト	5.2	11	2.0	0.1	1.3	9	4	0.60	-	4	B	102	○
2	フェライト	5.8	15	3.9	0.1	1.1	7	3	0.57	3.3	11	-	175	○
3	フェライト	3.5	83	1.1	0.11	1.11	8	3	0.44	-	9	B	83	○
4	フェライト	3	98	1.9	0.8	1.3	9	8	0.30	4.1	8	-	89	○
5	フェライト	4	66	2	0.5	1.11	10	8	0.30	3	6	B	109	○
6	フェライト	3.1	81	1.0	0.41	1.11	11	7	0.50	-	0	B	113	○
7	フェライト	2.1	81	1.8	0.19	1.11	10	8	1.00	-	0	B	103	○
8	フェライト	11	31	6.1	0.49	1.4	5	2	0.40	-	0	F	43	×
9	フェライト	加工組織	81	-	-	-	8	0	1.00	-	0	P	-	-
10	フェライト	7.1	61	-	-	-	8	0	-	-	0	F	-	-
11	フェライト	3.3	39	1.9	0.38	1.2	10	0	-	-	0	B	108	○
12	フェライト	1	79	3.3	0.5	1.83	7	5	0.40	-	0	B	118	○
13	フェライト	2.1	50	1.2	0.48	1.61	9	4	0.13	-	0	B+P	159	○
14	フェライト	3	40	-	-	-	6	3	0.15	-	0	B+P	-	-
15	フェライト	3.1	70	1.8	0.50	1.23	11	1	0.44	-	0	B+P	102	○

表4

鋼番	引張特性(ε=0.001/s)							予歪後A(BH)特性			高速引張(ε=1000/s)		[illegible]		[illegible]
	YS(MPa)	TS(MPa)	T.El%	[illegible]	YS×n	YR%	TS×T.El MPa%	予歪後の特性	予歪付与量%	BH[illegible]	σdyn	増加量	[illegible]	[illegible]	穴拡げ率(φ10mm)
1	610	530	31	0.09	44	85	21125	[illegible]	5	[illegible]	110	31.2	[illegible]	1.11	34
2	710	950	28	0.115	61	89	13880	[illegible]	5	[illegible]	106	30.1	[illegible]	1.30	28
3	642	450	35	0.105	51	77	15520	[illegible]	5	[illegible]	119	34.0	[illegible]	1.43	45
4	780	510	31	0.14	28	65	24180	[illegible]	5	[illegible]	103	30.5	[illegible]	1.30	28
5	690	510	31	0.12	81	75	18110	[illegible]	5	[illegible]	109	35.1	[illegible]	1.4	40
6	635	550	19	0.1	55	84	28500	[illegible]	5	[illegible]	107	40.8	[illegible]	1.45	45
7	643	500	31	0.11	53	75	23150	[illegible]	5	[illegible]	230	31.0	[illegible]	1.51	51
8	650	560	23	0.07	39	81	19515	[illegible]	5	[illegible]	201	-30.1	[illegible]	1.51	51
9	570	511	23	0.07	37	81	11500	[illegible]	5	[illegible]	830	-31.8	[illegible]	1.2	30
10	575	511	21	0.07	37	81	11150	[illegible]	5	[illegible]	831	-45.5	[illegible]	1.51	61
11	565	510	20	0.105	24	81	22430	[illegible]	5	[illegible]	834	41.1	[illegible]	1.1	30
12	810	800	20	0.105	52	81	20261	第二相[illegible]	5	[illegible]	340	75.1	[illegible]	1.52	52
13	1045	800	20	0.08	71	89	20760	[illegible]	5	[illegible]	1011	8.2	[illegible]	1.09	9
14	813	780	13	0.07	20	83	15876	第二相[illegible]	5	[illegible]	716	-45.2	[illegible]	[illegible]	52
15	850	474	37	0.11	54	79	24450	[illegible]	5	[illegible]	777	71.1	[illegible]	1.1	49